

FIRST QUARTERLY REPORT

for

CHARACTERIZATION OF RECOMBINATION AND CONTROL  
ELECTRODES FOR SPACECRAFT NICKEL-CADMIUM CELLS

JUNE 9, 1966 - SEPTEMBER 9, 1966

CONTRACT NO.: NAS 5-10241

Prepared by

GULTON INDUSTRIES, INC.  
ALKALINE BATTERY DIVISION  
212 Durham Ave.  
Metuchen, N. J.

For

GODDARD SPACE FLIGHT CENTER  
Greenbelt, Maryland

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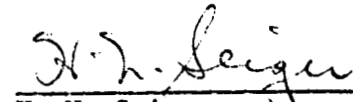
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CHARACTERIZATION OF RECOMBINATION AND CONTROL  
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by

S. Lerner and H. N. Seiger

ABSTRACT

A rapid method for determining the oxygen recombination ability of scavenger electrodes (both the Adhydrode<sup>®</sup> and fuel cell types) has been devised.

Two types of fuel cell electrodes, supplied by American Cyanamid and Leeson Moos, and Adhydrodes in various thicknesses and porosities, have been studied. The best recombination achieved for the Adhydrode has been on an electrode 0.055" thick and of 85% porosity. However, since the adhesion of the active material to the substrate is poor, the next best material, 0.020" thick and 70% porous, was chosen as the Adhydrode to be further studied in test cells. The American Cyanamid AB-6X fuel cell electrode is shown to have an oxygen recombination rate about 10 times greater than the best Adhydrode material.

An outline for the program work is also presented.

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## INTRODUCTION

High rate charging of sealed nickel-cadmium batteries is a desirable mode of charge. Its desirability is due to the necessity after deep discharge in low orbits, and also the efficiency of charge. High rate charging is avoided except where control of the amount of charge may be applied. By control, we must include some overcharge so that the input exceeds the capacity previously removed.

A control that has many attractive attributes is the Adhydrode<sup>®</sup> (the adsorbed hydrogen electrode). By careful setting of the trip point and the load resistor between the Adhydrode and the negative electrode, a single level can safely and adequately control high rate charge over a suitable range of temperatures. The Adhydrode is, in a manner of speaking, a self-powered transducer. If the cell characteristics change with use or time, the result is that the signal generated will reflect this change. This situation does, in fact occur. The negative electrodes recombine oxygen at decreasing rates over several hundred cycles. If we can get the oxygen recombination at faster rates, this disadvantage of the Adhydrode can be overcome. An oxygen getter or scavenger electrode appears to be a reasonable approach to this problem.

The objective of this program is to produce cells containing the Adhydrode and scavenger electrodes. This will be accomplished through an investigation of materials as a scavenger electrode, and the fabrication of such cells and batteries for evaluation.

## OUTLINE OF PROGRAM

The program has been divided into three main parts. The first involves improvement of scavenger electrodes, including fuel cell electrodes as well as passive Adhydrode catalysts. The second part of the program will be an evaluation of the third, or active, Adhydrode characteristics. The final part of the program will be devoted to testing cells containing the best features determined from the first two parts of the program.

### Testing of Scavenger Electrodes

Scavenger electrodes of the following thicknesses and porosities will be tested to determine their ability to recombine oxygen:

POROSITY %	THICKNESS (mils)
55	20
	32
	55
70	20
	32
	55
85	20
	32
	55

American Cyanimid's fuel cell electrode and a fuel cell electrode supplied by Leeson Moos Corp. will also be tested.

The best Adhydrode material and both fuel cell electrodes will be constructed into test cells.

### Test Electrodes and Cells

Construction of Test Cells. - Gulton positive, negative and Adhydrodes will be used. Plate dimensions are 2-3/4" x 2-3/4" x 0.020".

Cells will nominally be constructed of 10 positive and 11 negative plates. Scavenger electrodes will replace negative plates. The separator material will be Pellon 2505K, a non-woven nylon, and the electrolyte will be 34% KOH.

Formation. - The cells will be constructed and cycled using the following regime:

- a. Charged at C/2 for 2 hours
- b. Charged at C/10 for 16 hours
- c. Discharged at C/5 for 5 hours
- d. Charged at C/4 for 7 hours
- e. Discharged at C/5 for 5 hours
- f. Charged at C/4 for 7 hours
- g. Discharged at C/5 to -1.0 V

Test cells will have a capacity of 11 ampere-hours to 1.0 V.

#### Scavenger Electrodes

The best Adhydrodes arising from the above testing will be subjected to further testing in sealed cells.

Both the Cyanamid AB-6X and Leeson Moos fuel cell electrodes will also be tested in sealed cells.

Configuration of Adhydrode Catalysts. - Three methods of atmospheric contact will be used: (1) PVC screen, (2) metal screen and (3) grooved Adhydrodes.

To determine the effect of Adhydrode area on the rate of recombination, cells will be prepared having the negative to Adhydrode ratios of 10:1, 9:2, 8:3, and 7:4.

Testing of Adhydrode Catalysts. - Three cells of each method of atmospheric contact and each area ratio will be tested. The testing will include: (1) determination of steady state pressures, (2) pressure decay rate from the steady state during discharge, and (3) pressure decay from 25 psig on open circuit.

Fuel Cell Electrodes. - The fuel cell electrodes will be subject to the same testing procedure as the Adhydrode material. Initially, a PVC screen will be used and the negative to fuel cell ratio will be 10:1 in the case of the AB-6X material and 10:½ for the Leeson Moos material. The latter ratio arises from the fact that the Leeson Moos electrode is only active on one side. Three cells containing each fuel cell electrode will be tested.

Additional Testing. - The best Adhydrode and fuel cell configurations will be tested to determine their oxygen recombination ability in 20% aqueous KOH. Three cells of each kind will be tested.

### Active (Third) Electrode

Three locations for the active electrode will be studied; they are:

- (1) A "U" shaped electrode placed in a side position.
- (2) An electrode placed at one end of the pack.
- (3) An electrode placed in the center of the pack.

### Testing

When the optimum configurations for the scavenger and active electrodes have been determined, they will be used in combination in cells for final testing.

Temperature Characteristics. - The above cells shall be studied at four different temperatures, namely:  $-20^{\circ}\text{C}$ ,  $0^{\circ}\text{C}$ ,  $25^{\circ}\text{C}$ , and  $40^{\circ}\text{C}$ , at the following depths of discharge: 40%, 50%, and 60%. Testing shall consist of 1 week's cycling at each temperature and each depth of discharge using a 60-30 minute orbit.

Life Testing. - The best designed cells will be life tested during the work period at room temperature at both 40% and 60% depths of discharge. The orbit will consist of 30 minutes of discharge followed by 60 minutes of charge.

## EXPERIMENTAL PROCEDURES

### Synthesis of Scavenger Electrodes (Adhydrodes)

In order to obtain Adhydrodes of the desired thicknesses and porosities, for testing, several methods of synthesis were used.

55% Porous Electrodes. - The 0.020" electrodes were prepared by pressing 0.032" electrodes under 30 tons of pressure.

The 55 mil electrodes were obtained by 65 mil, 70% porous electrodes and compressing them with 30 tons.

70% Porous Electrodes. - The 32 and 20 mil electrodes were obtained from the Gulton Furnace Facility. Fifty-five mil electrodes were obtained by building up the 0.032" electrodes by adding additional catalyst material.

85% Porous Electrodes. - The 20 mil electrodes were obtained by mixing the active catalyst material with a sawdust expander in a ratio of 2/3 sawdust - 1/3 active material, placing the mixture on a perforated nickel sheet, and then removing the expander. The 0.055" electrodes were prepared by placing the active catalyst directly on a 20 mesh 0.007" nickel wire cloth.

### Fuel Cell Electrodes

Two fuel cell electrode materials were also obtained.

AB-6X Electrode. - This material, obtained from American Cyanamid, is 10 mils thick, has the active material attached to a metal wire cloth, and has both sides available as active material.

Leesona Moos Electrode. - In these electrodes, the active material is held together by a Teflon coating on one side. Therefore, the electrode has only one active surface. The active material is pressed on an expanded metal screen and is 0.030" thick.

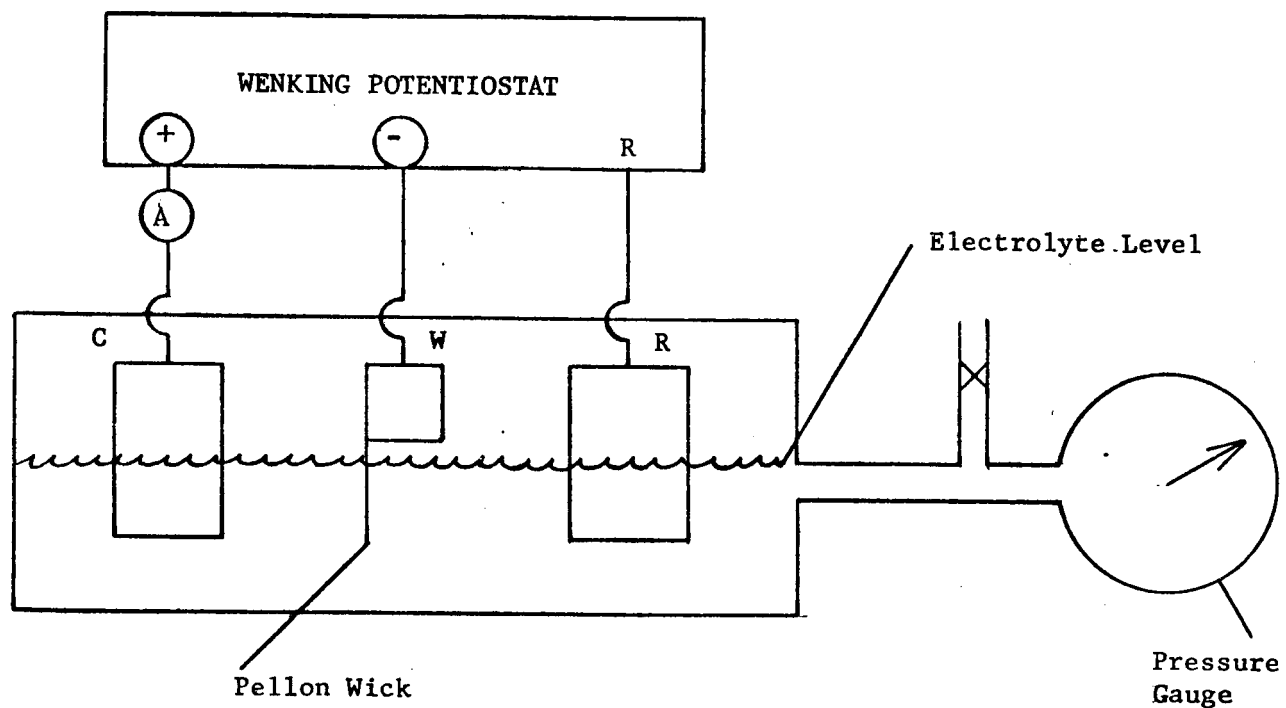
### Testing of Scavenger Electrodes (Adhydrodes & Fuel Cells)

Two methods of testing scavenger electrodes were used. The second method was needed since reproducible results could not be obtained by the first method.

First Method. - A sealed cell of VO-6 size was fabricated with a removable lucite top which was fitted with a pressure gauge. One well aged, partially charged, nickel oxide electrode was connected to the positive terminal and a nickel sinter electrode negative terminal of the cell. The test Adhydrode was connected to the pressure gauge. Both the nickel oxide and nickel sinter electrodes were partially submerged in the electrolyte. The test catalyst was in contact with the electrolyte through a Pellon 2505K wick attached to one side of the test plate.

The cell was then sealed, evacuated and pressurized with pure oxygen to 35 psig (50 psia). The nickel oxide electrode was connected to the reference electrode terminal of a Wenking Potentiostat, the nickel sinter electrode was connected to the counter electrode terminal, and the test Adhydrode to the working electrode terminal (Figure 1). A voltage of 1.31 V was impressed between the reference nickel oxide electrode and the working (Adhydrode) electrode. The current through the counter electrode was measured as a function of pressure. This current was the same as that through the test Adhydrode.

Second Method. - The same cell as used in the first method was employed. On the bottom of the cell, and insulated from it, was a small flooded nickel-cadmium cell which was kept at 1.31 V by an external nickel-cadmium cell. The test material was attached to the third terminal and was in contact with the electrolyte through a non-woven nylon (Pellon 2505K) wick, (Figure 2). The cell was then evacuated and pressurized to 45 psig (4 atm.) with oxygen. A precision (1%) 0.5 ohm resistor was placed between the test electrode and the flooded cell negative electrode and the voltage across the resistor was measured. This was repeated for 1 and 2 ohm resistors. The procedure was repeated again, this time starting at 1 atmosphere. From the voltage and resistance, the current through the test electrode was calculated. For each pressure, the current versus resistance was plotted and extrapolated to  $R = 0$ , the condition for a passive catalyst. The current,  $i_0$  ( $R = 0$ ) corrected for geometric area, was plotted against pressure. This graph,  $i_0$  vs.  $P$  is a measure of the recombination rate, for oxygen, of the material under test.



C = Counter Electrode - Ni Sinter

W = Working Electrode - Adhydrode

R = Reference Electrode - Ni Oxide Electrode

FIGURE 1.

ADHYDRODE TESTING APPARATUS

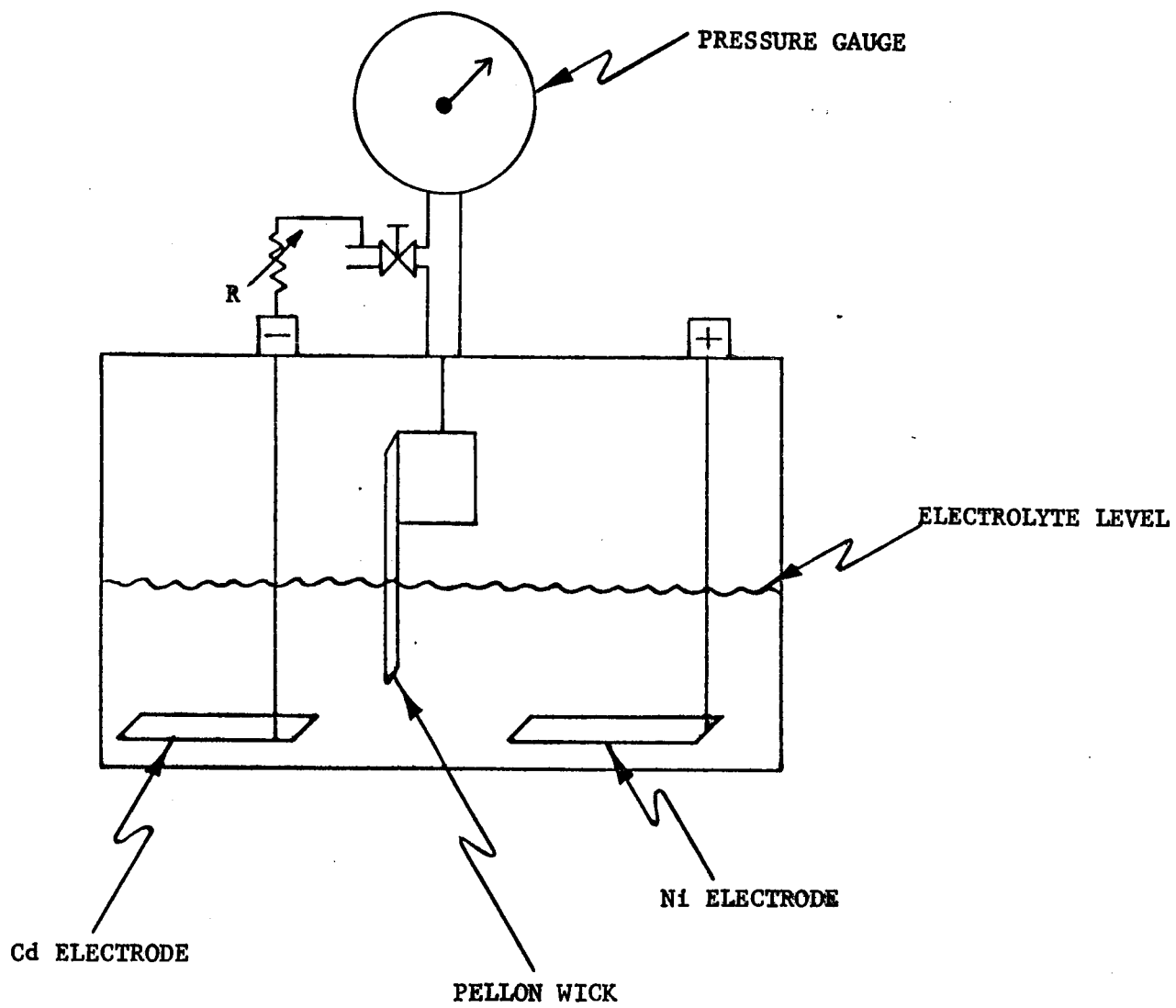


FIGURE 2. ADHYDRODE TESTING APPARATUS

## EXPERIMENTAL RESULTS & DISCUSSION

### Testing of Scavenger Electrodes (Adhydrodes & Fuel Cells)

The results of the tests are given in Table I and are graphically summarized in Figures 3 and 4. In the table, the Adhydrode materials are referred to as x/y, where x is the thickness in mils and y is the percent porosity.

As shown, in Figure 3, there is not very much difference in recombination ability of the different Adhydrode materials tested. The best scavenger is the 55 mil thick-85% porous material, and the poorest is the 20 mil thick-55% porous material. These results tend to indicate that a more realistic measure of recombination would be on the basis of a true surface area measurement, rather than on the basis of geometrical area alone.

While the 55 mil-85% porous Adhydrode apparently has the best recombination properties, it has been decided to use the 20 mil-70% porous Adhydrode for inclusion in test cells. There are several reasons for this choice; among them are: (1) there is not much difference in properties and the 20 mil-70% porous electrode is readily available, (2) the highly porous electrodes do not adhere well to the substrate material and tend to flake readily, which may cause internal shorting in a cell, and (3) the thick plate is almost three times the thickness of either one of the other electrodes.

Figure 4 shows the Leeson Moos electrode to be slightly better than the tested Adhydrodes, and the AB-6X electrode to be about ten times as good as the Adhydrodes. Indeed, other work at these laboratories has shown, under actual cell conditions, not only that the recombination rate of the AB-6X fuel cell electrode is ten times that of Adhydrodes, but this recombination is almost temperature independent.

TABLE I

P vs.  $i_o$  FOR VARIOUS SCAVENGER ELECTRODES

P	LIMITING CURRENT, $i_o$ , AS R $\longrightarrow$ 0							
	20/55	20/70	20/85	32/70	55/55	55/70	55/85	Leesona
4	1.40	2.24	1.86	2.08	1.91	1.98	2.72	3.94
3	1.20	2.02	1.66	1.80	1.62	1.81	2.40	3.42
2	1.02	1.80	1.31	1.68	1.44	1.50	1.90	2.83
1	0.88	1.51	1.04	1.35	1.20	1.20	1.59	2.60

P = Atmospheres

 $i_o$  = milliamperes/sq. inch

x/y = thickness (mils)/porosity (%)

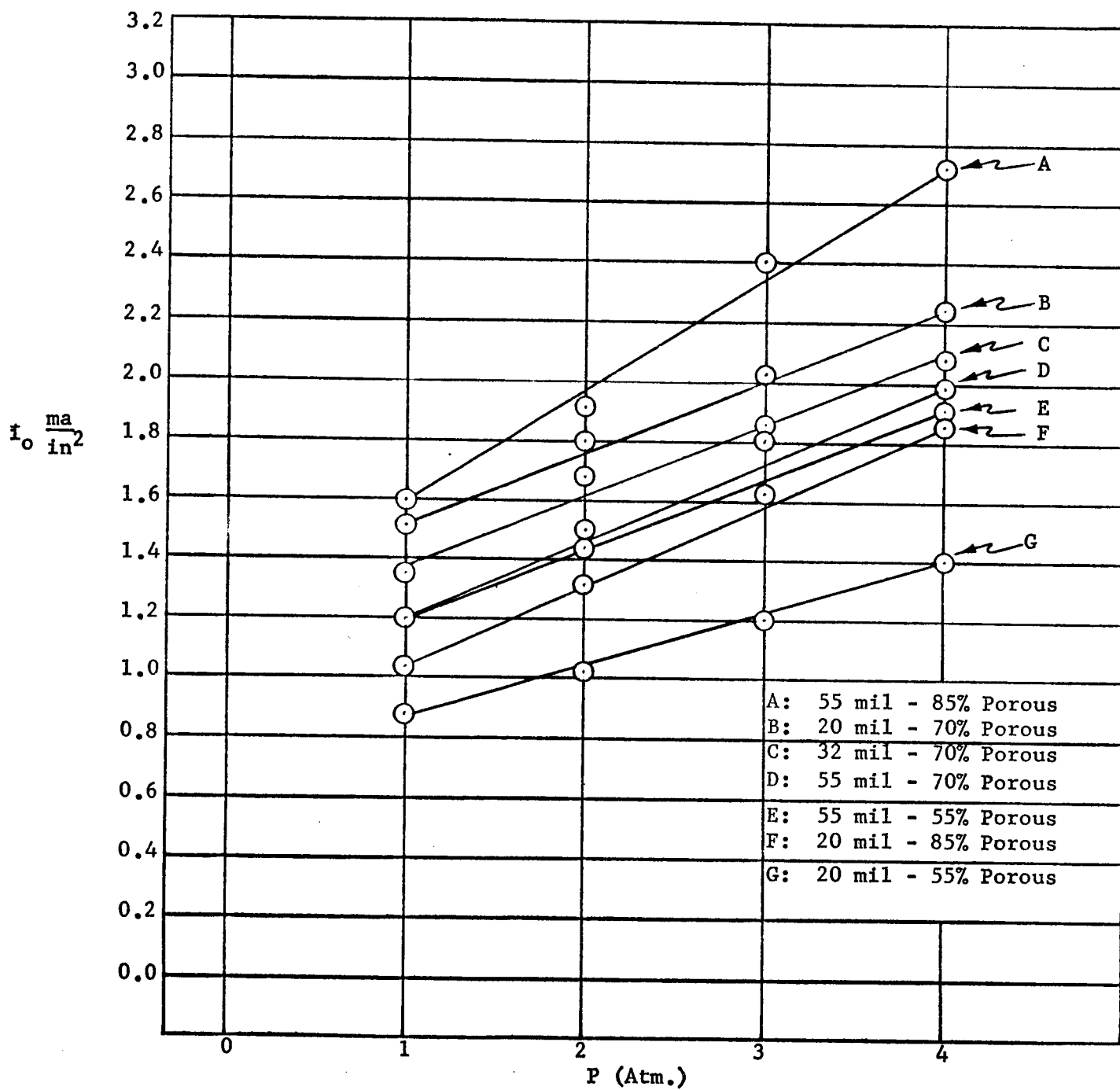


FIGURE 3. TEST OF PASSIVE ADHYDRODES

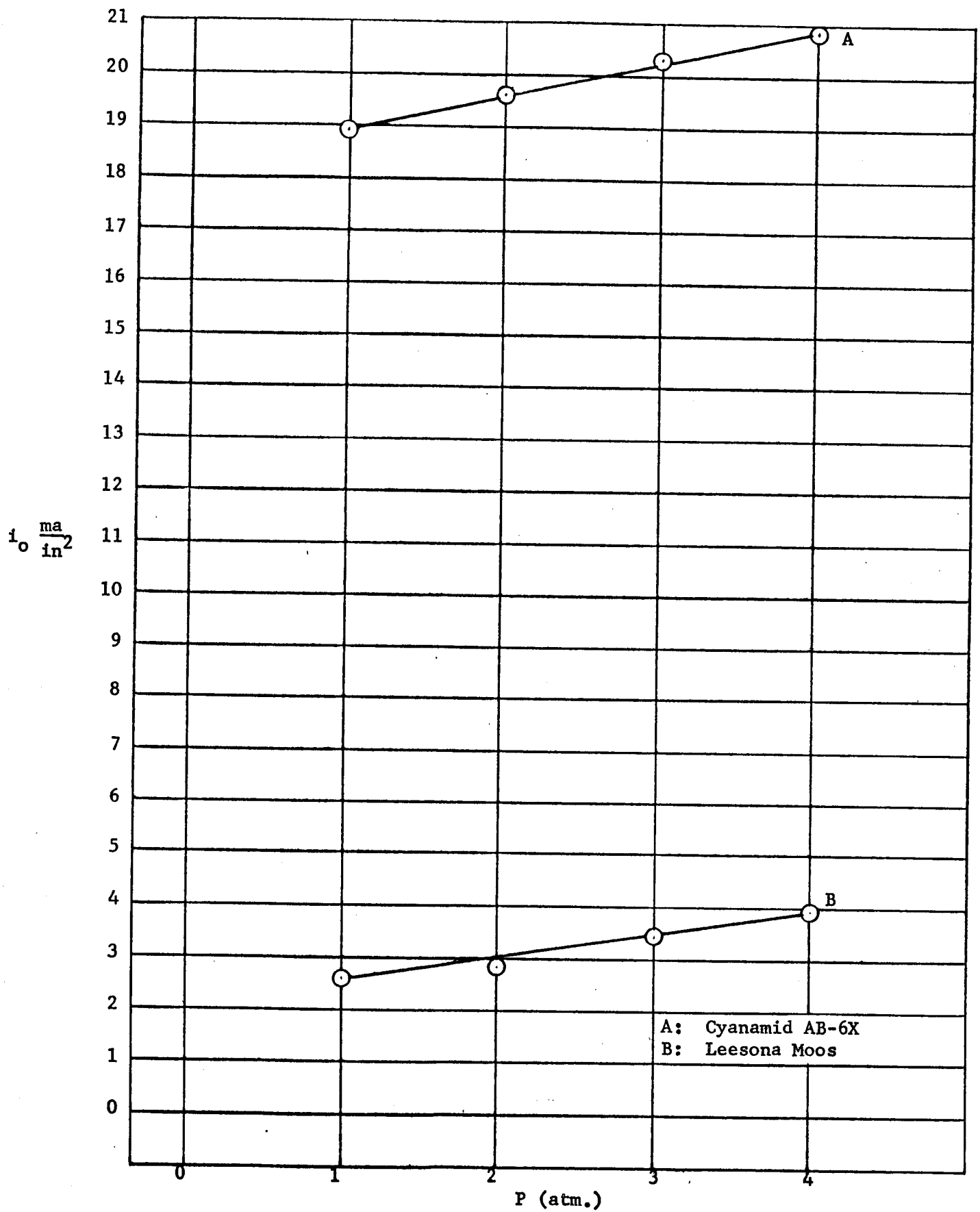


FIGURE 4. TESTING OF PASSIVE FUEL CELL ELECTRODES

#### FUTURE WORK

Cells containing passive Adhydrodes and passive fuel cell electrodes are being constructed and testing will be initiated shortly.

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